Office of Force Transformation
Department of Defense
Transformation Trends 7 December 04

"The focus today is on speed, it's on precision, it's on mobility, stealth, and networked forces. And we're continuing to improve capabilities in those areas."

Defense Secretary Donald Rumsfeld, November 2004

Wolf PAC

Distributed Operations Experiment

The Office of Force Transformation (OFT) is undertaking an initiative – *Wolf PAC* – to explore *command* and *control* (C2) of geographically dispersed, networked, autonomous and semi-autonomous assets. Forces are becoming increasingly burdened by the lack of a coherent strategy to "*control*" large numbers of dispersed assets. Distributing those assets geographically, loosely federated by networks, only serves to increase the complexity of these controlling challenges.

Coordinating effects, let alone commanding individual capabilities for coherent purpose, has always been a challenge for commanders. Since leveraging information age phenomena is the command of the day, then a concerted effort must be made to understand the behavior and effects of large numbers of maneuvering assets in a networked environment. If networked relationships are fundamentally changing the character of warfare so too must informational and organizational relationships change.

The classical approach to "c*ommand* and *control*" may be inadequate to the challenges of directing the collective behavior of humans in a networked environment. In fact, the existing cultural and organizational approaches to C2 may actually impede the adaptive qualities needed for autonomous and semi-autonomous elements to be successful. The more appropriate terms may be to *coordinate* with *coherence (?C2).*[1] But whether we choose terms such as 'coordinate, collaborate or cooperate' the

[1] *Coordinate* with c*oherence* is influenced by Thomas Malone's *The Future of Work*. Malone holds the Patrick J. McGovern Professor of Information Systems chair at the MIT Sloan School of Management and foresees a workplace revolution that is dramatically changing organizational structures and the roles that employees play in them. He argues that current notions about decentralization merely scratch the surface of what will be possible as technological and economic forces make

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appropriate terminology is not as relevant as understanding the dynamic tension between *command* and *self-synchronization*; between *control* and *self-organization*; and between the cultural and organizational mismatches that might arise in networked military actions.

As an experimental venue, *Wolf PAC* will serve to resolve some of most stressing challenges of tactical and operational networked *command* and *control.* As an operational experiment, *Wolf PAC* will use a wide variety of assets and will investigate whether or not a new approach to *command* and *control* can be engineered practically and advanced operationally. If successful, *Wolf PAC* will generate operationally relevant lessons that provide the commanders with a new means for *command* & *control* of distributed, adaptive operations in the Information Age.

Transformational Objective

The Office of Force Transformation (*OFT*) investigates and incubates emerging capabilities not articulated as requirements by the services. Its fiscal and intellectual support serve to catalyze the changes needed to explore, develop and experiment with concept–technology pairings embedded in chassis–module combinations. *OFT's* aim is to take fast, bold and specific steps to provide a positive path toward changing the force through operational experimentation.

- ✓ fast – get transaction rates up
- ✓ bold – reach past what can be comfortably achieved, and
- ✓ specific – provide a roadmap so that DoD does not revert to past practices

The broader transformational objective of *Wolf PAC* will be to perform operational experiments that examine *command* and *control* challenges of distributed, networked forces in joint Sea Based and Special Operations missions. *OFT's* intent is to increase experimental transaction rates to generate higher learning rates so that the DoD can more quickly produce investment options that adapt to an uncertain future. An option-based hedging strategy is achieved by increasing numbers and diversity, by creating a force relevant at many scales and by overmatching competitors with complexity through investment and engagement in every threatening niche. This options-based strategy is specifically designed to create a more tactically stable force – a force that values speed in maneuverability and requires modularity for rapid reconfiguration. Such a force can rapidly adapt to dynamic conditions and consistently win. It is also a force where tactical learning is highly prized.

Tactical learning serves as a hedge against an adversaries cost imposing strategy, such as terror, by generating a better understanding of a chaotic world at the relevant scale for proximate resolution. But controlling local chaos cannot be achieved from strategic distance – it must be accomplished by fundamentally recognizing what is occurring at the relevant scale by local emersion and from a well-rehearsed experiential perspective. Tactical learning from operational experimentation also provides a means for gaining experience in critical operational mission areas without having to falsely predict future mission or engagement areas. By deliberately experiencing as many operational options within the tightest cycle times DoD will generate the best opportunity for organizational learning. Organizational and tactical learning driven by increased experimental rates serves to give our nation a more strategically relevant approach to cost for assessing future acquisitions.

"*command* and *control*" leadership increasingly less useful. The *Wolf PAC* concept of *coordination* with *coherence* will play a far more prominent role in distributed operations, distributed networked forces and *Wolf PAC* like activities.

High numbers of co-evolutionary cycles and high rates of learning alone can not solve the complex challenges of *command* and *control*, but a dedicated focus on operational experimentation will go a long way to developing the new first principles of Information Age Warfare. By exploring the underlying engineering of distributed operations, *Wolf PAC* may provide assured access solutions to littoral or urban contested zones.[2]

For successful competitive advantage in these contested zones, the ability to moderate the potential chaos of self-organizing networks is a prerequisite. The advancement of the complex art of war and the development of associated analytical tools are needed to explore new concepts of operations for delivering fires, consumables and information to these chaotic, competitive battlespaces. *OFT* believes this is best accomplished through the experience that operational experimentation provides.

Distributed Operations: Networked forces outfight non-networked forces

In the 21st Century, warfare will require agility and the application of tailored forces against more diffuse threats. These threats will retreat to the most complex terrain and will take advantage of both local and global seams in modern society. As part of an overall Joint Force, SOF and SOF-like forces must be prepared to support multiple simultaneous, distributed, decentralized battles and campaigns against both conventional and unconventional adaptive enemies. The threat has been watching intently and has designed denial and deception strategies, which may blunt or negate our technological superiority or may inhibit a force that is over-reliant on strike and single lines of advance. Therefore it is incumbent upon tomorrow's joint forces to be interdependently networked and coherent to *"conduct simultaneous,* distributed *and parallel operations synergistically across the levels of warfare, in depth."*[3]

The idea of dispersed or distributed operations is not new. Using distributed operations to conduct multi-dimensional and simultaneous attacks from different directions has long been desired by great commanders. But new threats and new emerging C4ISR technological opportunities require a better understanding of the inherent *command* and *control* challenges of distributed, networked forces and the necessity for these forces to rapidly adapt to changing conditions. Distributed and adaptive operations, embedded in the *Wolf PAC* experiment, places greater emphasis on decentralized decision-making, dynamic maneuver, and degradation of an enemy's options.

A distributed adaptive operation accepts the enduring nature of the fog, friction, uncertainty, chance, and chaos. It is specifically designed to deal with the ambiguity of threats and latency in command in order to help commanders map emerging patterns that technology alone cannot resolve. The result is that the contributions of diversity, persistence, granularity, and discrimination all need to be applied proportionally faster than an opponents means allow.

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[2] The "littoral" is considered to be the prototypical "complex adaptive environment" because of the number of intersecting elements such its complex topography (underwater and near land interface), volume of commercial shipping traffic (high signal to noise ratio – clutter management, pattern discrimination), and numerous threats (anti-ship cruise missiles, mines, aircraft, coastal artillery, swarming small boats, and diesel submarines) in aggregate seek to prevent access and confound solutions. See Yaneer Bar-Yam, "Multi-scale Analysis of Littoral Warfare," CNO Strategic Studies Technical Paper, 2002.

[3] Joint Warfare and Conflict Resolution Perspectives.

Distributed adaptive operations assume that each element or unit of action can autonomously perform particular tasks, using multiple measurable methods. It also assumes that each element may carry out an entire task itself, or it may coordinate with other elements that perform parts of the task. Distributed elements empowered to seize the initiative, to exploit success, and to reconfigure themselves in response to threats and opportunities, are all coherently guided by commander's intent. Organizations composed of these elements, will learn and adapt to successes and failures as the situation changes. Consequently, future joint forces will come to realize that to succeed and survive in Information Age warfare they must act in a distributed adaptive manner.

By enabling elements of a Joint Force to make decisions and set initial conditions faster than the opponent, distributed operations facilitates our ability to adapt in scale and method as the operational or tactical situation dictates. Most importantly, it allows the commander to control tempo for sustaining continuous pressure against an opponent for as little or as long as it takes to fulfill operational aims. The operational art of blending intelligence, logistics, and operations for maneuver advantage all serve to disorient, dislocate, destroy and defeat an opponent. But the ability to take effective action for this purpose requires a more thorough understanding of how to *command* and *control* distributed networked forces. The key objective of Wolf PAC is so a "future Joint Force will be capable of conducting and supporting *distributed non-linear operations* in a singular battlespace.[4]

OFT's Wolf PAC initiative exists, applicable at the operational and tactical levels of war, to bridge the functions of actionable intelligence, sense and respond logistics (S&RL), and distributed adaptive operations.[5] The coherent multi-axis approach that a geographically dispersed; distributed networked force offers, creates overmatching complexity by ensuring confusion, ambiguity and chaos in our adversary's mind. This concerted effort serves to direct effective joint actions that influence and shape future engagements and to produce a decisive psychological, positional and temporal competitive advantage over any emerging adversary in the Information Age.

The pace of coherent maneuverability coupled to task-organized distributed units, acting interdependently; enables rapid adaptation for dominating the competition. The result is that the adversary is presented with a greater degree of uncertainty regarding our locations, intentions, and objectives. Subsequently, networked-enabled forces operating as geo-dispersed units conducting distributed operations can:

- Influence actions broadly
- Catalyze networked effects
- Create high transaction rates
- Mass effects without massing forces
- Adapt rapidly to dynamic conditions
- Execute distributed or concentrated ops
- Self-organize decision making – *defined by simple rule sets*
- Generate "organic intelligence" *and exploit Global intelligence*

[4] Donald H. Rumsfeld, Joint Operating Concept, Nov. 2003.

[5] *Sense* and *Respond Logistics (S&RL)* is a network-centric, knowledge-driven, knowledge-guided concept that sustains modular, reconfigurable force capabilities to execute Joint and Coalition effects-based operations and to provide precise, adaptive, agile support for achievement of commander's intent. S&RL relies upon highly adaptive, self-synchronizing, and dynamic physical and functional processes, employing and enhancing operational cognitive knowledge development, sense-making, and decision support.

Wolf PAC Objective

The *Wolf PAC* experimental venue is focused on operationally relevant and "battle field" quality learning without the losses or risks associated with combat. The resulting experience will serve to reinforce the competitive advantages of increased speed of command, the networked effects of high numbers of assets, and principles of modularity at technical and operational levels – each contributing to more rapid force projection and effective engagement strategies.

The fog and friction of war has and will always confound commanders because competition continuously increases complexity at a revolutionary pace in order to survive and win. The rapidly increasing complexity that emerges from dynamic competition favors a quick partial solution sooner over a ponderous perfect solution later. As a result, different suite of first-order analytical tools and rudimentary thumb rules supporting a high number of operational experiments will more quickly provide an approximate design for a force that can rapidly change in dynamic competition.

The approach presented by *Wolf PAC* serves to solve some of tomorrow's complex problems today by experiencing high numbers of co-evolutionary cycles, in a short period, using imperfect surrogates. The iterative outcome will provide continuous feedback thereby generating operationally relevant experience so that our forces have the capacity to adapt as threats emerge.

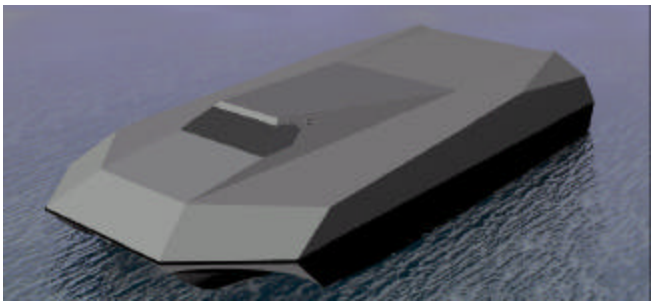
Operational Surrogates

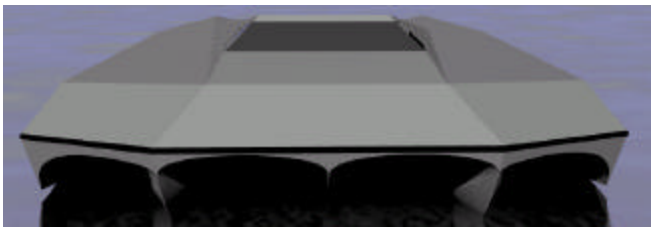
To survive and win in future littoral operations will require a diverse variety of assets amalgamated as a networked, distributed joint force. It demands a force that shares information widely and takes advantage of pattern ambiguity, readily consumes increased information volume and can adapt to ever increasing complex conditions. Scale-matched assets are critical to the architectural structure of *Wolf PAC*.

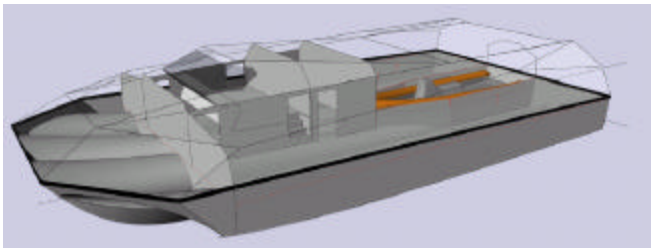
Stiletto represents one of the many assets to be used for distributed operations, purposely designed to investigate the underlying rules for success and survival in complex environments such as the littoral. *Stiletto* is a composite – fiber, high-speed vessel, designed to explore the scalability of non-mechanical dynamic lift, composite construction technology, high-speed performance and its application to military operations. *Stiletto* and craft like her are not meant to replace or compete with capital ships of the line; instead they are intended to have capital potential in every hull.

Stiletto's specific characteristics incorporates modularity at multiple levels and uses an electronic keel (data bus) for rapid mission reconfiguration which provides the necessary flexibility for SOF-like forces to deploy, modify and tailor capabilities to emerging challenges. *Stiletto* also explores high payload fractions capable of shallow water operations for speed of deployment and access to unprepared and contested zones. *Stiletto's* main purpose will be to accommodate, launch and retrieve an 11m-RIB as well as launch and operate unmanned vehicles to include Unmanned Aerial Vehicles (UAV) from the

upper deck. *Stiletto* will also represent one of the many nodes needed in a circulatory system regulated by the demand centered neural network of *Sense* and *Respond Logistics*.[6]







[6] *Sense* and *Respond Logistics (S&RL)* is an OFT initiative that seeks to transform how the defense department sustains geographically dispersed and distributed adaptive forces. More information on *S&RL* can be found at www.oft.osd.mil/initiatives/srl/srl.cfm.

Wolf PAC Operational Experimentation

Wolf PAC will explore emerging concept-technology pairings to develop near term solutions to *coordinate with coherence (?C2)* large numbers of geographically dispersed networked assets. *Wolf PAC* has three key objectives:

a. Create Options

i. Acting on NCW principles of war, produce physical and virtual surrogates that allocate joint networked capabilities

ii. Preserve design teams and intellectual talent to create a stable commercial market

iii. Loosen requirements – foster incentives for innovation by setting broad objectives

iv. Increase variety and numbers

v. Broaden the technology base

b. Increase Transaction Rates

i. Provide a venue for developing operational experience through immersion

ii. Establish high numbers of operational experiments with imperfect surrogates

iii. Create new knowledge and tacit understanding of complex problems

c. Ensure Higher Rates of Learning

i. Produce High numbers of co-evolutionary cycles to solve for complex problems

ii. Iterate organizational relationships that dynamically adapt to context (mission) dependent and scale relevant challenges

iii. Observe, understand and influence behaviors at the scale that events occur

d. Create Overmatching Complexity

i. Engineer for collective behavior and design toward networked effects

ii. Understand connection topologies and connection strengths

iii. Increase diversity at the right scale

iv. Synchronize high numbers of networked capabilities

Experimental Approach

***Wolf PAC* will describe, develop, and explore measurable design rules & metrics**

a. Design principles for Distributed Operations and Distributed Networked Forces[7]

- ***Recombination***: ability to aggregate, distribute or interchange physical, informational or logical elements and connections
- ***Dispersion***: avoid spatial, informational, or logical centers of gravity thereby confounding adversary C2 and scouting resources
- ***Mobility***: sufficient speed for rapid relocation of elements and reconfiguration of elemental collectives (physical or logical means)
- ***Pattern masking & ambiguity***: envelope management performance. Greater numbers of elements provide physically smaller elements and the ability to hide among the clutter
- ***Proximity***: uncouple physical component's direct proximity to threat (effect of mass without the massing of forces or elements)
- ***Flexibility***: principles of modularity – Fluid system substructures with range of modular interoperability options – measure of adaptivity
- ***Persistence***: ability to operate w/o disruption of cyclic logistics and operations

b. **Investigate networked behavior of large numbers of geographically dispersed assets**.

- ***Speed of response***: Diffusion rates, Number of Nodes
- ***Speed of command***: Average path length, neutrality
- ***Self-synchronization***: Path Horizon, Auto-catalytic Sets
- ***Shared awareness***: Clustering distribution, organizational relationships, between-ness

c. Deliverables

- Technical
  - Model – evaluate – validate – modify simulation tools & evolutionary algorithms to emulate complex environments.
  - Determine network relationships between surrogates
  - Establish standards, protocols, and interfaces for surrogates
- Operational
  - CONOPS for distributed adaptive operations – how many in what variety & combination using NCW conceptual framework. Determine how to employ, deploy, sustain, and C2 a distributed, networked force
  - Applied engineering solutions to *coordinate* with *coherence (?C2) Wolf PAC*

[7] Cares, Jeffrey R., Raymond Christian and Robert Manke, *Fundamentals of Distributed, Networked Forces and the Engineering of Distributed Systems,* NUWC-NPT Technical Report 11,366, 9 May 2002.

Key Partnerships with Wolf PAC

a. NAVSEA Naval Undersea Warfare Command (NUWC):
   i. Technical Program Manager of *Stiletto* & *Gladius*
   ii. Responsible for *Wolf PAC* design & implementation
   iii. *Wolf SIM* implementation
   iv. UUV collaboration with multiple undersea assets

b. NAVSEA Carderock Combatant Craft Department (CCD)
   i. Craft / construction design review, oversight and modification
   ii. Integration of operational GSE
   iii. Electronic keel development, installation and evaluation (Azimuth Inc.)
   iv. Craft experimentation

c. NAVAIR Avionics Department:
   i. Experimental monitoring and Surveillance system "Suretrack"
   ii. DCGS-N/TES test-bed for C2ISR
   iii. UAV launch and recovery from the water and vessels
   iv. Laser installation on vessels for operational use

d. OSD NII:
   i. Swarming case study implementation with developed algorithms

e. Office of Naval Research (ONR):
   i. High Speed test craft data collaboration and utilization
   ii. *Sea Coaster, Sea Flyer, HDV-100* experimental utilization
   iii. USSV (low & high speed) experimental utilization
   iv. Sensor network contributions

f. Naval Research Lab (NRL) & Sandia Labs: SOCKETS
   i. MAHAN: (Mobile Ad Hoc Area Network) - aggregate of spatially dispersed and possibly mobile, sensing, effecting and communicating nodes that are connected into a coherent operational entity by means of a robust communications backbone.
   ii. NIMBUS - rapid response to detected events within a sensor field via an auto-configuring network capable of dynamic management of information flow.

iii. CICADA – scaleable, autonomous, GPS-aided, micro-glider UAVs designed to fold into an efficient package for loading into various types of pods as a deployment mechanism for NIMBUS

iv. Collective behavior – behavioral interdependency rules for large numbers of autonomous elements.

v. Copperfield II /AIS/SEI – Automatic Identification System and Specific Emitter Identification system

vi. TACSAT-1 / VMOC – Operationally Responsive Space Experiment with the Virtual Mission Operations Center - a collaboration gateway for tactical access to space. Log onto VMOC at tacsat.nrl-dc.smil.mil

g. Naval Post Graduate School (NPS):

i. System Engineering, Spec Ops Student participation and integration of Surveillance and Target Acquisition Network (STAN) to *Wolf PAC*

ii. TSSV: NPS student participation for *Wolf PAC* system engineering design

h. *Stiletto*: Non-mechanical dynamic-lift high-speed composite vessel

i. Operational experimental platform to launch and retrieve USVs & UAVs

ii. Store, launch, operate and retrieve an 11m-RIB from the stern

iii. Venue to investigate scale free architecture of large numbers of unmanned vehicles

iv. Naval Architecture: M-Ship Co.

v. Knight & Carver: Vessel construction

vi. SP Systems: optimization design of composite structures.

i. *Gladius:* Ducted-fan, mechanical dynamic-lift high-speed composite vessel

i. Operational experimental platform to launch and retrieve UAVs

j. *SEALION*: Semi-submersing high-speed aluminum vessel

i. Operational experimental platform for signature reduction, ISR and C4I

ii. Oregon Iron Works: Builder

iii. Naval Architecture: NAVSEA CCD

k. Mindtel Inc: Physio-informatics

i. Systems based, physiologically robust, reference architecture for interactive human-computer interfaces to increase operational throughput of information.

l. Icosystems: Genetic algorithms

i. Real Options applications to the design, development and deployment of new defense systems

ii. Resource allocation, agent-based modeling using genetic algorithms and genetic programming analyzing trade-offs between communications, data processing, mission objectives and other operationally relevant needs.

iii. Testing tools and methods using an Auto-Catalytic Engineering (ACE) process for Distributed Networked Forces.

m. The Rendon Group: Intermodal Hub Failure

i. Distributed Operations provide a high option approach for transportation infrastructure support. Analysis of high-speed intermodal vessels to provide interdependent connectivity for logistical circulatory needs to be addressed.

n. Alidade Inc: Distributed Networked Forces

i. Development of the mathematical algorithms, engineering principles and operational rules for Distributed Networked Forces

o. Synergy: Sense & Respond Logistics agent based operational prototype

p. Azimuth Inc: Electronic Keel Design / Build / Install

q. SOCOM: Operational experimentation of *Stiletto,* GFE & concept generation of *Wolf PAC*

r. USMC: Operational experimentation with & concept generation of *Wolf PAC*

s. Regional Combatant Commanders: operational venue, coordination and personnel.

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Stiletto Operational Experiment

Stiletto is designed to explore the scalability of non-mechanical dynamic lift, composite constructed technology, high-speed performance and its application to military operations. *Stiletto's* specific characteristics such as high payload fractions capable of shallow water operations provide the necessary flexibility and speed for deployment of SOF-like forces. This advanced technology craft will feature high-speed with efficiency (flat power curves), smooth ride quality in high sea states (shock mitigation), high payload-fractions (ease of reconfigurability), and stability at all speeds.

Design Dimensions
• Length - 80 feet • Beam - 40 feet • Draft - 3.0 feet • Displacement - 50-70 tons

Machinery, Propulsion, Power & Fuel
• Total Power Rating - 6,600 Horsepower: Four (4) Caterpillar Electronic Marine Propulsion Engines (Model C-32, DITTA rated at 1650 Hp @2300 rpm).

The engine sets (2 each) will be located in the P&S Central Displacement Sections (CDS). They will be staggered with the outboard engines closer to the transom and the inboard engines located forward and near the centerline of the CDS.

• Four (4) Surface Drives • Two (2) 2,500-gallon fuel tanks

Stiletto will be driven by four (4) Surface Drives. The propellers will be positioned as far outboard on the CDS as possible to allow clearance for the 11m-RIB. A cage or enclosure will be designed to surround the drives and protect the RIB crew and guide the boat into the transom well.

Performance Objectives
• Max Full-Load Speed - *50 to 55 knots* • Max Light-Ship Speed - *55 to 60 knots* • Max Range Cruising Speed – *30 to 40 knots* • Range @ Cruising Speed – *500 nm* • Payload Fraction *40-50 %*

Hull Lines

- Non-mechanical dynamic lift configuration:
  - Four Planing Tunnels (PT) and two Central Displacement Sections (CDS)
    - The Port & Starboard Skirts (S) are non-structural and independent of the hull.
    - The centerline skirt is considered non-structural.
    - The depth of the CDS determines final displacement - achieved by vertically moving the hull bottom below the chines.
    - The depth of the forepeak of the CDS provides shock mitigation.
    - The volume of the centerline skirt above the waterline provides additional shock mitigation.

Structural Design
Stiletto will be a carbon-fiber design (along with other composite materials) to create a lightweight, high-payload fraction craft. The design will integrate structural components with interior arrangements to minimize weight. Tradeoffs will be evaluated for longitudinal, frame, stanchion and bulkhead spacing. Design standards will be engineering based and compared to ABS and/or DNV design rules.

General Arrangements

Stiletto will have three primary areas: • driving facility • crew seating area • large cargo area. An enclosed head will be located in the crew seating area. There will be one main deck with an elevated bridge deck forward. The main deck in the cargo area will have a well deck with a retractable stern gate to accommodate an 11m-RIB. The overhead will have ladder access for the launching of Unmanned Aerial Vehicles (UAV). Entry to the ship will be via P & S doors.